A Study on the Automation of Scanner Matching

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ABSTRACT

Scanner matching based on CD or patterning contours has been demonstrated in past works. All of these published works require extensive wafer metrology. In contrast, this work extends a previously proposed optical pattern matching method that requires little metrology by adding the component requirements and the procedure for creating an automation flow. In a test case, we matched an ASML XT:1900i using a DOE to an ASML NXT:1950i scanner using FlexRay. The matching was conducted on a 4x nm process test layer as a development vehicle for the 2x nm product nodes. The paper summarizes the before and after matching data and analysis, with future opportunities for improvements suggested.

Keywords: Scanner matching, optical pattern matching, source optimization

1. INTRODUCTION

From the early immersion scanners (XT:1700i in 2007) to the current state-of-the-art systems (NXT:1950i), the single-tool CD uniformity as well as tool-to-tool CD-through-pitch matching performance has improved significantly (~70%). Nevertheless, during the same period, the imaging requirements have been pushed due to device node scaling. One key requirement is that scanners are lithographically matched to ensure consistent quality and eliminate manufacturing bottlenecks. A complicating factor in meeting these requirements is that two illumination platforms exist for the NXT/XT 19X0i scanners. One system is called Aerial-XP and is based on diffractive optical elements (DOEs), while the other is called FlexRay™ and supports freeform illumination sources. Of the many possible cases, matching Aerial-XP to FlexRay systems poses the toughest challenge. Pattern matching across a production fleet of immersion scanners remains a major challenge.

1.1 Sources of patterning variations

Scanner imaging and matching performance is affected by many factors. Among these are design differences between scanner configurations and generations, setup offsets during installation, component and software upgrades, aging-induced drift, and maintenance status. Finding the root cause of a measured patterning difference requires experience and may involve inspection of maintenance records, extensive lithography simulations, and wafer verification. Even if the source is found, the root cause may not be removable, e.g. in the case of design differences or when a major repair cannot be slotted into the production schedule. At times, software-based scanner tuning rather than root-cause removal becomes the only viable option to achieve matching.

We have analyzed the imaging variability across ASML immersion scanners (NXT, XT:1950i, XT:1900i, XT:1700i) where all the scanners are assumed to be within the manufacturer's specifications. We simulated top and bottom CD, as well as CD asymmetry and uniformity, for various critical patterns for the 4x process node printed at best focus. Tool parameter perturbations were set at either 75% of their specification range or at the largest observed deviation in our production fleet. These resulting CD variations were analyzed for both same-machine-type and mixed-machine-type scenarios. The applied machine-to-machine (M2M) parametric perturbations and their resulting CD impact are listed in table 1. The relative CD impact per parameter is plotted in Fig. 1.

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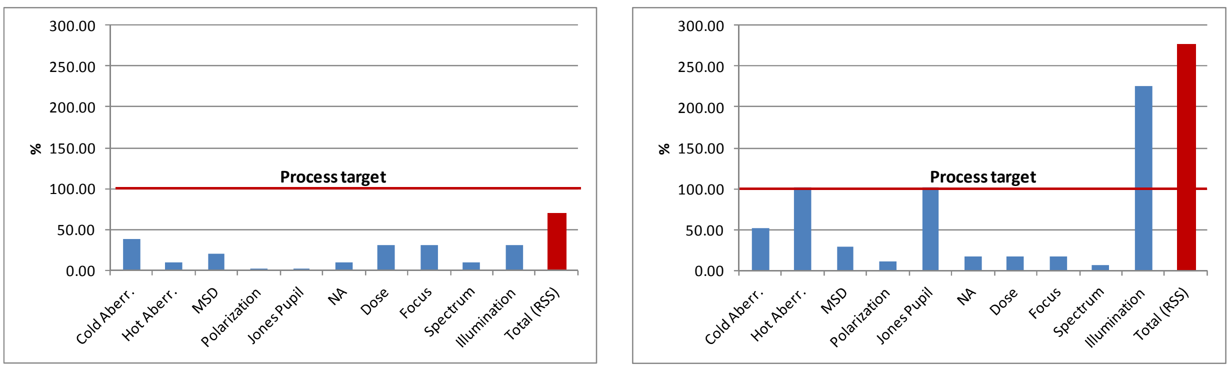
Table 1. Parametric estimation on scanner process mismatching patterning impacts

Parameters	M2M differences (simulation conditions)	CD mismatch (nm) (Same machine type)	CD mismatch (nm) (Mixed machine types)
Lens Aberration (cold)	M2M max (odd/even) zernikes delta < 1.5nm	0.4	0.6
Lens Aberration (hot)	Lens heating difference due to difference lens	0.1	1.5
MSD	dMSD X/Y=25% MSD X/Y. Used 2D patterns	0.2	0.3
Polarization	different machine types: dIPS < 0.3%	0.0	0.1
Jones Pupil	Only applies when including previous lens type	0.0	1.5
Numerical Aperture	1nm per 0.001 dNA	0.1	0.2
Dose	affects wafer CDU only	0.3	0.3
Focus	affects wafer CDU only	0.3	0.3
Laser spectrum	long term stability within +/- 0.03pm	0.1	0.1
Illumination pupil	Details given in the text	Flexray system: 0.3	Flexray/Aerial mixed system: 2-4 or above



(a) (b)

Figure 1. Estimated contributions from each parameter to the CD mismatch between two ASML immersion scanners, with process target of CD mismatch tolerance = 1 nm. (a) Same machine type (b) Mixed machine types.

Within a properly maintained production fleet, based on simple summation of contributions, our data indicates an expected CD range variation of 1.8nm for a fleet of same-type scanners. This includes illumination-source variation. For this scenario, the largest sources of variation are cold-lens aberration, MSD and illumination differences from machine to machine. In contrast, the estimated CD variation for a fleet of mixed-type scanners is quite large, up to 5x the variation for same-type scanners. If we assume that all contributions are random and uncorrelated and therefore use quadratic variance summation (RSS, or root-square summation value), the expected CD variation in a same type of fleet is 0.7nm RSS, and in mixed-type fleet is about 4nm RSS. This latter number is more realistic, but still exceeds an aggressively preset budget (1nm) for advanced nodes. Note that the illumination source difference is the largest contributor (40% or larger) in the CD variation when different machine types are considered. This number was calculated with non-Flexray systems, i.e. from the pupil intensity variations measured for DOEs.

During previous research, we concluded that the DOE pupil area can be divided into three zones: Zone 1 is the pole areas, Zone 2 is the +10% surrounding the poles, and the background Zone 3 is the rest of the pupil. We performed through-pitch (40-1000nm) dense/iso-line-space simulations using Dipole and Quasar illuminations, and found that the maximum though-pitch CD mismatch can be predicted using the following linear correlation:

$$\Delta CD_{max,\ Through\text{-}pitch} = A * Zone\_\Delta value\ (\%) \qquad (1)$$

Here A is between 0.5 to 0.8 for Zone 1 and 2, and 9-10 for Zone 3. We also found the intensity mismatch between the DOE's on two different scanners can often be ranked by Zone 3 > Zone 2 > Zone 1, in terms of percentage. This is

largely due to the performance degradation of the optical components running in high-volume manufacturing over time as well as due to running the DOEs at the edge of the permitted setting range where pole smearing is the largest. DOEs are in our analysis a primary cause of M2M CD variation in ASML scanners equipped with Aerial illuminators.

1.2 Source Optimization (SO) or Source-mask Optimization (SMO)

The patterning procedure requires a photo-mask and the corresponding illumination source. Changing either of the two will result in an increase in CD variation. For the purpose of reducing M2M CD mismatch, we have the option of optimizing the source (SO), the mask (MO), or both (SMO). Either of these methods can be used to change the CDs on the second scanner to match the reference scanner. In our opinion, SMO is best suited for new process development, while SO is best for correcting or enhancing a photo process that is already in production.

If the root cause of the CD variation is due to the deviation of a specific scanner's optical condition with regard to the reference, ideally the variation should be corrected by adjusting the scanner optics. In practice, this means adjusting the illumination source. For Aerial-XP scanners, the tunable illumination parameters are NA, sigma and pupicom. Despite the small number of knobs, reasonable matching improvements can be made. FlexRay systems offer significantly increased control over the source pupil, resulting in process optimization or pattern matching to a higher precision. In conclusion, SO is a viable software solution to manufacturing fabs: it can deliver significant improvement in matching performance, requires only changes in tool settings that are easily applied, and – due to the absence of mask making - provides very fast turnaround time for both Aerial and Flexray systems.

In comparison, SMO tends to require more time and cost due to the mask making involved and consequently is less attractive in a high-volume manufacturing environment. Therefore, whenever SO is able to deliver the matching performance in line with the imaging budget for a node and layer, it is favored by manufacturing. For those cases where SO is not able to deliver the required performance, e.g. in the case of litho processes with k1 very close to the Rayleigh limit or with very limited DOF or when dealing with multiple scanner generations, SMO may be the only viable option.

1.3 Introduction to the scope and purpose of the current work

We have discussed that the illumination source is commonly the largest source of pattern variation between scanners. We have also discussed the capability and efficiency of SO in compensating the small CD differences caused by small optical differences between scanners. This work focuses on SO for scanner pattern matching, with particular attention to automation using optical models only in order to speed up the time-to-solution in high volume manufacturing (HVM).

In order to quickly eliminate a majority of the matching issues for an entire scanner fleet during the first pass, a pure optical-model-based, zero-wafer-metrology matching method has been presented in one of our previous papers [9]. This work extends the optical pattern matching method (OPM) by adding the component requirements and the procedures needed for automation of the method. The application example is matching an XT:1900i using a DOE to an NXT:1950i scanner using FlexRay. The matching was executed on a 4x nm process test layer as a development vehicle for the 2x nm product nodes. The paper summarizes the before and after matching data and analysis with future opportunities for improvements suggested.

2. METHOD AND PROCEDURE

2.1 Source optimization method

A source optimization algorithm generally includes four elements: an objective function, seed pixels, sensitivity of the objective function to the source parameters, and the optimization method. The objective function E (also called cost function) can be constructed using a root-mean-square (RMS) difference based on a Hamiltonian function, image log slope, DOF, MEEF, and/or edge placement error, to quantify the patterning difference between the reference scanner and the second scanner using a given mask and resist process. In the cases of SO for pattern matching where small perturbations in both source and aerial images are expected, the objective function can be simplified to the RMS difference of a set of simulated CDs between scanners, either at the best focus or throughout a focus-exposure matrix (FEM). In any case, the objective function is a function of optical parameters which includes source, mask and other scanner optics and resists parameters.

SO starts with an initial condition - a set of seed pixels in the source pupil. The source pupil is optically the pupil plane of the projection optics where the lens aperture is also placed. For SO in pattern matching, the seed pixels are created by duplicating the current illumination source on the reference scanner. We assume that the existing source has been optimized for the imaging and DOF requirements of the process and the source is only to be perturbed slightly from the existing source to compensate for the optical differences existing in the rest of the parts of the optical system on the second scanner. This perturbation is the result of source optimization guided by the sensitivity values for reduction of the objective function to all tunable source (and/or lens) parameters. Fixing all other parameters during the pattern matching except the source, E is simplified to merely a function of source $E(p)$, in which p is the vector of the tunable source and lens parameters, and the minimization of the objective function is equivalent to finding the zero of the nonlinear function $DE(p)$, $DE(p)=\nabla E/\nabla p$, the *Jacobian* or sensitivity of the objective function to the source parameters. ASML's PMFC uses the Newton's method for iterative optimization. Since the optimization problem is approximately quadratic, the method has good convergence speed and stability.

2.2 Optical pattern matching method

There are two components in simulating lithographic processes: the optical intensity distribution and the photo-resist exposure kinetics. Resist modeling is required in order to predict the wafer CD accurately. Two factors affect the model calibration accuracy: coverage of pattern types and measurement noise. Therefore, we need to measure enough structures with enough repeating measurements to build an accurate resist model for simulations - a highly time-consuming step. With the assumption that resist or other processing is well matched, aerial image differences between scanners should be the major source of variation. Theoretically, if one could bring two scanners to the exact same aerial image intensity distribution at the wafer plane, the resist patterning by two scanners should be well matched. Therefore, the basis of OPM is a) with a matched track flow, the differences shown in wafer CDs between scanners can be attributed to differences in scanner optics and exposure process; b) The purpose of OPM optimizations is to eliminate the differences in wafer CDs by minimizing the aerial image differences. Below is a formal definition of OPM.

Optical intensity equation defined in spatial domain:

$$I(r)=\iint dr_1 dr_2\left[j(r_1-r_2)m(r_1)m^*(r_2)h(r-r_1)h^*(r-r_2)\right] \tag{2}$$

Where, $r = (x, y)$ is the 2D spatial coordinate, $j(r)$ is the effective illumination source shape that has dependence on tunable pupil parameters (such as sigma, Flexray freeform source intensity, etc), $m(r)$ is the mask amplitude function, and $h(r)$ is the projection lens transfer function that has dependence on tunable lens parameters (such as NA). The asterisk superscript represents the complex conjugation operation.

See Figure 2 for the one-dimensional CD definition of line space patterns:

$$I(x_1) = I(x_2) = T,\ \text{optical CD} = x_2 - x_1 \tag{3}$$

$$R(x_1) = R(x_2) = T',\ \text{resist CD} = x_2' - x_1' \tag{4}$$

Where x_1 and x_2 define the intersects of the threshold and aerial image or resist profile. $I(x)$ is the optical intensity at wafer plane (Eqn. 2), while $R(x)$ is the resist profile. A constant threshold is needed to define an optical CD.

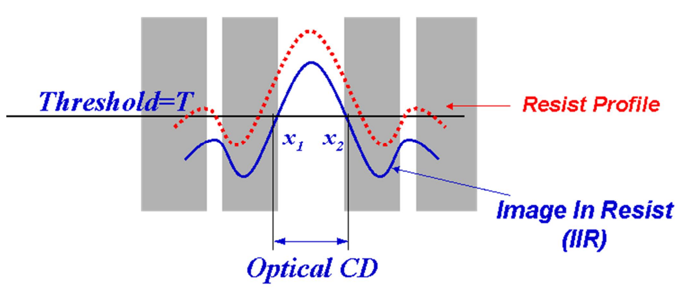


Figure 2. 1D aerial image and resist profile. CD is defined by a threshold that is determined by target wafer CD

OPM definition:

$$\boldsymbol{argmin}_p\{E\},\ E = SQRT[\textstyle\sum_n(optical\ CD_{ref} - optical\ CD_{TBM})^2/n] \tag{5}$$

where SQRT is the square root operation, subscript p is the vector of tunable illumination parameters, subscript *ref* indicates the reference scanner, and subscript *TBM* means the second scanner (To-Be-Matched scanner).

OPM represents a practical solution in scanner matching with small compromises. It allows eliminating or significantly reducing the wafer metrology in the scanner matching process, which has formed the basis for scanner matching automation and high throughput of results.

2.3 Multi-step pattern matching procedure

Consolidating from previous manufacturing quality control and problem-shooting experiences, a four-step staged pattern matching procedure is proposed as follows:

1. Scanner optics and process analysis
2. Illumination pupil comparison and matching
3. 1D pattern matching using generic through-pitch CDs
4. 2D pattern matching using Production CDs with generic through-pitch CDs

Step 1 requires a hardware check with both the reference and the second (TBM) scanner. The check may cover any aspect of the scanner parameters against the vendor specification values and the historical production fleet averages. The scope of the parametric inspection may vary depending on the range and frequency of the production equipment maintenance records. In general, the scope should cover cold lens aberration (ILIAS), beam (pointing, shape and size), laser performance, stray light (SAMOS), illumination slit uniformity, alignment and stage vibration (MSD and MA). The second check will include the track flows, resist batches and metrology to validate the assumption that the scanner is the only variable that contributed to pattern mismatches. If any of the checks indicate an out-of spec issue, the issue should be resolved right away. Note that this step only checks whether scanner parameters are set correctly or whether there are any indications of hardware or resist/metrology issues. It does not necessarily imply that all these parameters have to be matched. There are scanners in a fleet that could have different optical designs (machine models) or are at different upgrade option levels.

Step 2 focuses on illumination source only: the pupils from the two scanners should be captured (PUPILIAS) and compared. In most cases, the two measured pupils will show some difference, even in the case of FlexRay pupils. However, the impact that the difference in pupils has on patterning can be accurately predicted. Dedicated software can be provided for optical CD simulations using either a production mask or a generic mask that is suited for the particular illumination condition. If the simulation indicates that a measurable CD offset can be expected from the two pupils, a source matching will need to be performed. Test wafers should be exposed to verify the result. For a pair of scanners that are the same type or have nearly identical optics (e.g. XT:1950i and NXT:1950i), we expect the pattern mismatch will largely disappear. In the case of scanners with different optics, we would make a decision based on data whether the CD mismatch is now within the budget for the layer and therefore matching is completed, or further steps are required for additional pattern matching.

Steps 3 and 4 are scanner pattern matching steps. As explained above, we have determined at this stage that the other parts of the scanner have caused the patterning difference, not the source, and there is nothing else to fix. In a majority of the situations, the patterning difference is small (e.g. < 5nm) and SO can be performed to reduce the difference between the two scanners. The difference in steps 3 and 4 is what mask patterns are used for optimizing the pupil on the TBM scanner. Using generic patterns (1D through-pitch range) has the advantage of zero simulation setup overhead and can be fully automated. Using 2D production patterns usually requires a time-consuming manual setup (including creating a gauge file containing these pattern positions) and access to the production layout database. In return for this extra effort, it is reasonable to expect more accurate matching and fewer iterations of wafer testing.

3. IMPLEMENTATION

The implementation of the proposed multi-step scanner pattern matching procedure is visualized in Figure 3, in which Step 1 (optics and process analysis) is a manual step that is defined and supported by tool maintenance protocol and software; Step 2 (illumination matching) uses a ASML software called CD-based Pupil Qualification (CDPQ); Step 3 and 4 (1D/2D pattern matching) are based on another ASML software package called Optical CD Matcher (OPM); the generated scanner matching recipe is first uploaded to ASML's Lithoserver (OTAS) and then linked with manufacturing fabs' proprietary Recipe Administrator (RA) software. The automation of the pattern matching flow also requires a few databases: ASML Lithoserver database (OTAS DB), Advanced Process Control database (APC DB), Reticle Stream File database (Streamfile DB), and CD metrology coordinates (Metrology DB). Further details about the automation flow will be given in §3.3.

3.1 CDPQ

The goal of CDPQ is to quantify the CD impact resulting from the difference between the target pupil (what is wanted) and the measured pupil (what is actually made on the lithography system). This is done using simulations, because imaging in photoresist (with subsequent SEM measurements) can confound the pupil effects with other effects that have a CD impact. Using a simulation, we can directly identify the pupil effects on product CDs. The mask pattern used has several predefined line/space combinations and end-of-line structures, each with a different sensitivity to the pupil. CDPQ will report the predicted delta CD per feature and use this as the metric for the pupil quality.

3.2 OPM

Optical CD Method Pattern Matcher (OPM) is built on ASML's Pattern Matcher FullChip (PMFC) software. PMFC belongs to the LithoTuner software family that uses litho simulation to reduce litho process variation in a high volume manufacturing wafer fab environment. PMFC is designed for CD-based scanner matching on a full product layout. PMFC tunes the optical parameters of the TBM scanner to minimize the CD differences between the TBM and reference scanner using resist models. OPM is a custom addition to PMFC that performs pattern matching using simulated optical CDs without involving resist models. The accuracy of the OPM optical models is the result of ASML/Zeiss proprietary optics design information for every scanner type that is built into PMFC. The accuracy of the optical models for any particular scanner is further enhanced by using the Scanner Fingerprint File (SFF) utility. Please refer to the OPM based pattern matching flow illustrated in Figure 4.

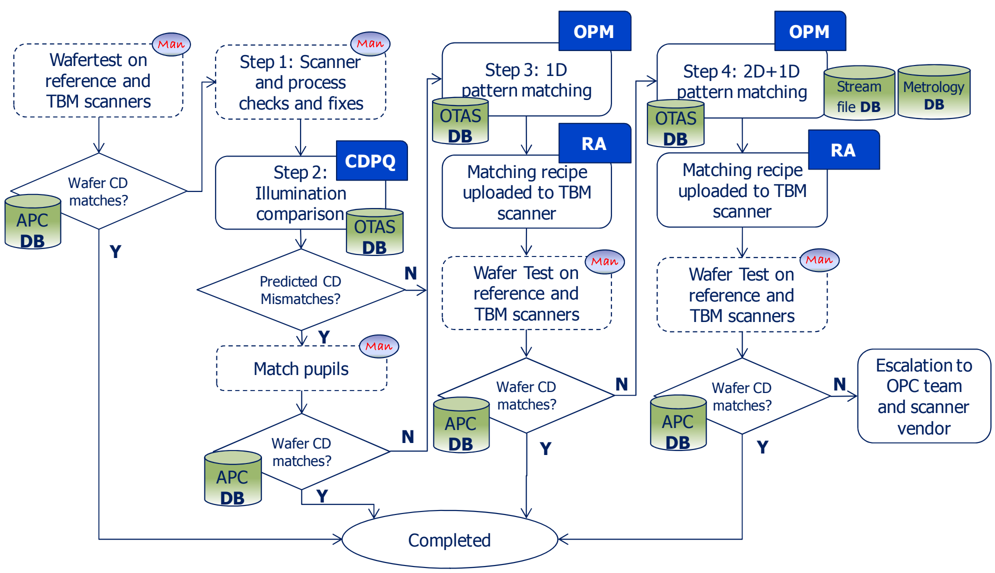


Figure 3. Multi-step scanner pattern matching procedure, and the required software components and databases (DB) for automation. Dashed frame means it is a manual operation step

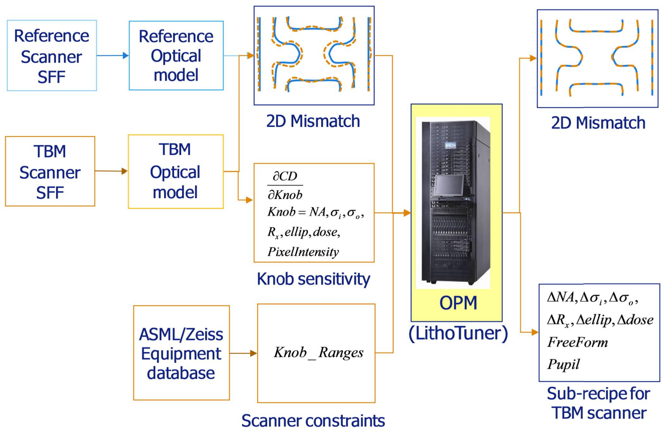


Figure 4. Scanner pattern matching based on OPM

3.3 The automation of pattern matching

The software automation of any process requires that data can be collected and stored automatically, that logical decisions can be made based on analysis of the data, that actions can be taken based on decisions, and that proper data and functional interfaces are available on the equipment. For the pattern matching flow illustrated in Figure 3, data collection automation is supported by the OTAS DB (scanner metrology data and lot reports) and the APC DB (wafer data); pattern matching decisions are made from wafer data received in the APC DB; the logical control for moving forward with pattern matching steps is made by the scripts in APC DB; the function of checking for pupil mismatch based on predicting CD mismatches in Step 1 is supported by CDPQ and results stored in the OTAS DB; the function of performing 1D or 1D/2D patterning matching using SO in Step 3 and 4 is supported by OPM, in which 2D production pattern based matching will require access to the Streamfile DB and the Metrology DB. Finally, the OPM pattern matching (SO) scanner sub-recipes are uploaded to the OTAS DB and then pushed to the TBM scanner; while at the same time, RA can link to the new sub-recipes and will order the scanner to use the pertinent sub-recipes when exposing production lots. In our current implementation, a few process steps in the matching flow are still manual, such as the scanner hardware checks and the process/wafer lot selection. For using 2D production patterns during the matching, a Metrology DB also needs to be either manually created or exported using SEM metrology software. This setup can be done during the process transfer from R&D to HVM. Because the OPM flow skips two major SEM metrology steps for the two scanner model calibrations that are present in PMFC, OPM reduces the resource overhead and turnaround time for scanner matching and reduces reliance on R&D involvement, thereby enhancing the effective adoption by HVM fabs.

4. EXPERIMENT AND RESULTS

4.1 Equipment and setup

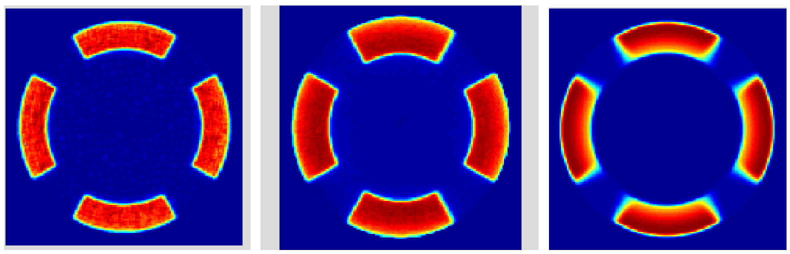
To verify the matching approach, we tested it using a XT:1900i and a NXT:1950i scanner, both running leading edge 4x nm processing. The XT:1900i scanner is equipped with an Aerial-XP Illuminator and the NXT:1950i with a FlexRay illuminator. Both scanners used identical customized TE-like polarization. We used the NXT:1950i scanner in R&D as a reference scanner and the XT:1900i as the to-be-matched machine. To guarantee measurable process differences, the starting illumination conditions for the XT:1900i used different sigma values from the reference scanner (Figure 5).

The matching test was completed for pattern matching Step 2 and Step 3/4, for which the supporting software (CDPQ, OPM) and databases have been implemented. Consistent with our approach, the matching was done with only a set of measurable scanner parameters (pupil measurement, dynamics etc.) and did not involve measured SEM data. Scanner Fingerprint Files (SFFs) were generated through the LithoTuner GUI. The impact of observed source differences on CDs was first predicted by CDPQ. Using 1D test features and 2D product features, the illumination tuning was completed

with OPM. We performed several runs with different combinations of matching knobs such as NA, sigma, focus drilling range and PUPICOM settings to assess the correction capability of the scanner. The efficacy of our approach was assessed by CD-SEM measurement of the critical process features both before and after matching.

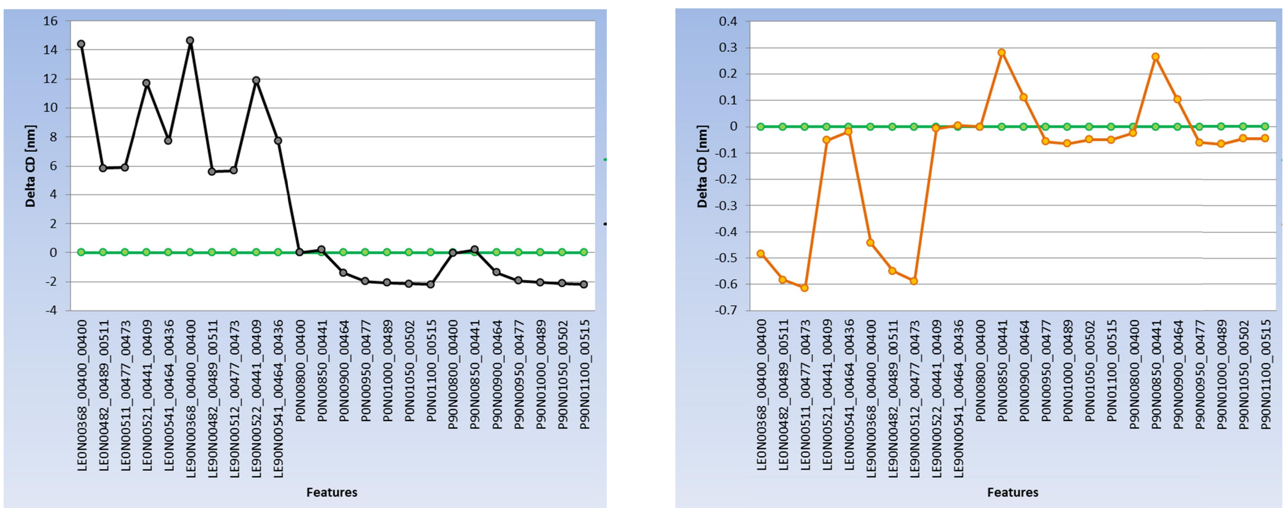
4.2 CD-based pupil qualification

As intended in our setup, the TBM pupil (called Initial value #1 for OPM) resulted in significant CD differences relative to the reference. Source matching, which is expected to remove the intentional sigma offset in our experimental design, did indeed remove most of the CD differences. The resulting matched source is labeled “Initial value #2 for OPM”. See Figures 5 and 6.



a) b) c)

Figure 5. Pupil profiles from: a) Reference NXT; b) Before sigma matching (Initial value #1 for OPM); c) After sigma matching (Initial value #2 for OPM).

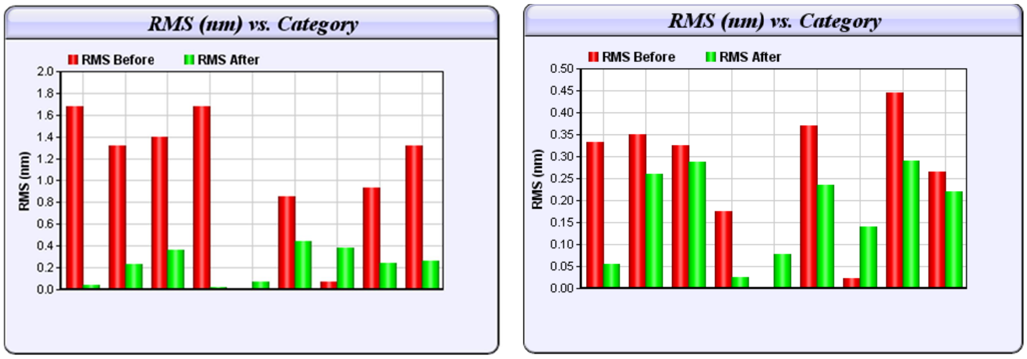


a) b)

Figure 6. CDPQ CD prediction results using: a) Before sigma matching (Initial value #1 for OPM); b) After sigma matching (Initial value #2 for OPM).

4.3 Matching with OPM

OPM pattern matching using 1D+2D features was performed as the next step in the automation flow. We did this both for Initial value #1 – representing OPM only (using the original, or intentionally de-matched pupil as the initial value for OPM), as well as for Initial value #2 – representing source matching followed by OPM matching (OPM with the matched pupil as the initial value). While Initial value #1 showed a larger RMS improvement from the OPM step, Initial value #2 resulted in a better final matching result, thereby validating our multi-step approach.



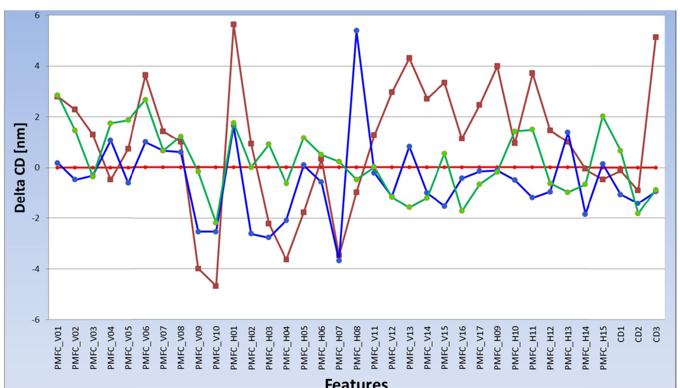
a) b)

Figure 7. OPM predicted RMS before and after matching with a) Initial value #1; b) Initial value #2.

4.4 Matching verification on product

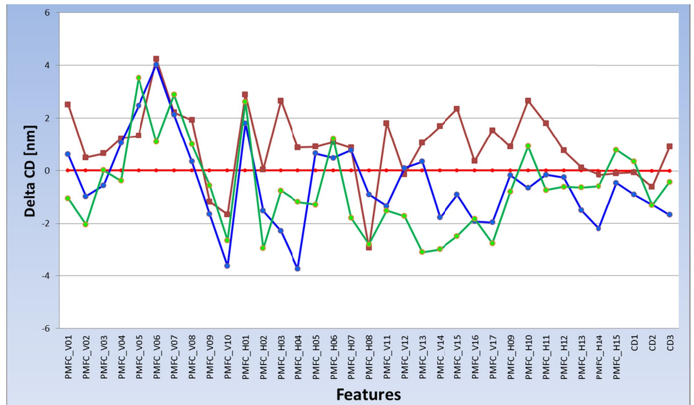
Wafer verification was performed with CD SEM as the last step in the pattern matching flow in Figure 3. Figures 8 and 9 confirmed that with initial pupil seed pixels, we have achieved significant matching improvement at the best focus.

Successful matching was also confirmed by Process Window (PW) analysis. Comparing Figures 10 and 11, after the OPM matching, the overlapping process windows for production 2D features have been significantly improved. However, different initial values used with OPM (original or match pupil) yielded a difference in the PW results.



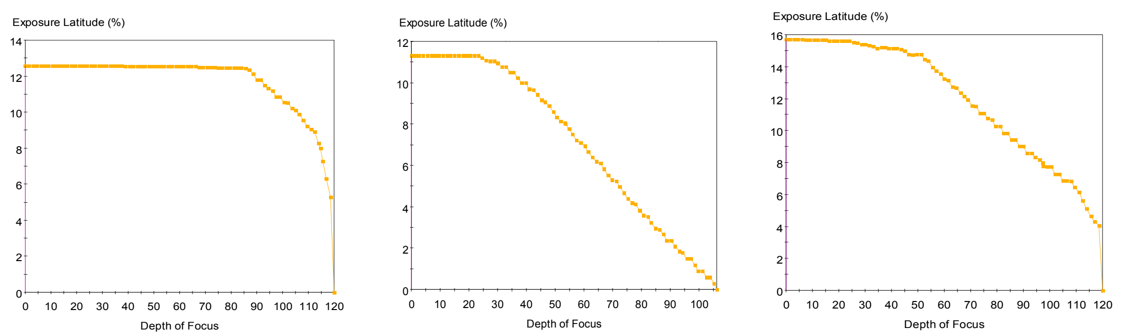
Measure	before matching (Initial value #1)	after OPM matching (Initial value #1 as seed pixels)	after OPM matching (Initial value #1 seeding and with PUPICOM)
MAX	5.63	5.38	2.84
MIN	-4.68	-3.66	-2.18
MAX-MIN	10.31	9.04	5.02
RMS	2.69	1.68	1.32

Figure 8. 2D+1D CD OPM matching data using Initial value #1: Red – reference scanner; brown – before matching; blue – matching without PUPICOM, green – matching with PUPICOM.



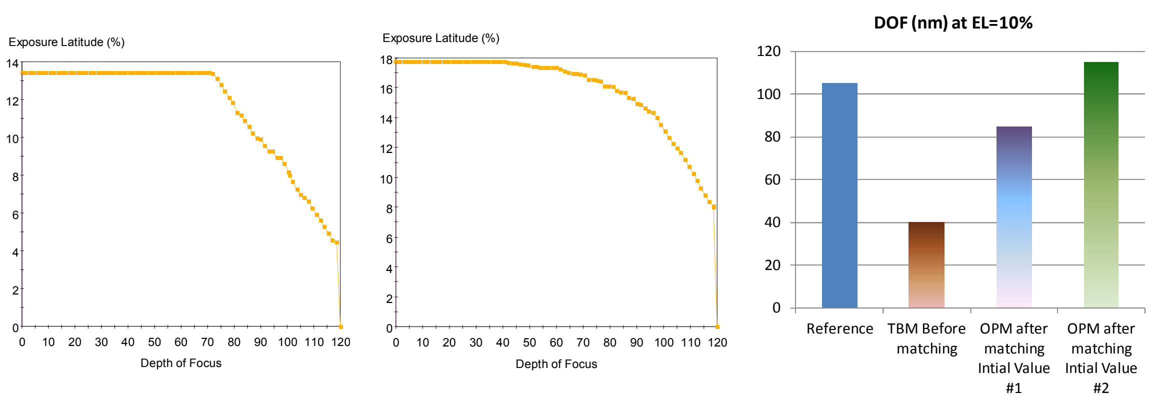
Measure	before matching (Initial value #1)	after Source matching (Initial value #2 from step 2)	after OPM matching (Initial value #2 as seed pixels)	after OPM matching (Initial value #2 seeding and with PUPICOM)
MAX	5.63	4.24	4.03	3.53
MIN	-4.68	-2.91	-3.72	-3.09
MAX-MIN	10.31	7.15	7.75	6.62
RMS	2.69	1.66	1.68	1.80

Figure 9. 2D+1D CD OPM matching data using Initial value #2. Red – reference scanner; brown – source matching (Initial value #2) only result; blue- OPM matching without PUPICOM, green – OPM with PUPICOM.



a: PW of NXT (Reference)   b: PW of XT:1900i at initial value #1   c: PW of XT:1900i at initial value #2

Figure 10. PW comparison before OPM: (b) and (c) are TBM scanner's PWs before/after pupil matching



a: PW of XT:1900i -OPM by init. val. #1   b: PW of XT:1900i -OPM by init. val. #2   c) DOF at EL=10%

Figure 11. PWs after OPM matching: (a) and b) are OPM results on TBM from two initial values

CONCLUSIONS AND RECOMMENDATIONS

In this work, a multi-step, systematic scanner-matching procedure was proposed, a pattern matching automation flow was studied, and the initial software components that support the implementation of the automation were created and tested. The test was completed for pattern matching procedure Step 2 and Step 3/4, for which the supporting software (CDPQ, OPM) and the databases have been implemented. Based on the test data, we concluded: (a) illumination pupil comparison and matching (Step 2) is able to verify if the illumination source is the dominant component in the CD mismatch; (b) direct pupil matching provides an excellent initial value (seed pixels) for the pattern matching, improves matching performance and reduces SO iterations; (c) Optical CD Matching (OPM) significantly reduces the RMS of the CD mismatches; (d) the improved matching performance from applying OPM is observed at best focus as well as through the process window; (e) without a rigorous process-window CD matching objective function, the post-matching process window has a dependency on the initial SO conditions and may not be fully optimized. We also observed from previous works that the process window by wafer data can perturb significantly depending on the resist used, especially at the larger defocus and dose-offset values. In pursuit of rigorous process-window matching while keeping the simplicity of OPM and the automation flow, we plan to investigate whether enabling of the following features in LithoTuner software can be beneficial: (1) the ability to define a process-window objective function for scanner matching SO; (2) the ability to use a set of predefined resist parameters that can better capture the pattern failing locations through dose and focus, therefore more accurately predicting the actual process window during SO.

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